

Attorney's Docket No.: 460-010107-US(PAR)

PATENT

03CD
#6

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: LAINEMA et al.

Group No.:

Serial No.: 09/766,238

Filed: 01/19/01

Examiner:

For: A METHOD FOR FILTERING DIGITAL IMAGES, AND A FILTERING DEVICE

Commissioner of Patents and Trademarks
Washington, D.C. 20231

TRANSMITTAL OF CERTIFIED COPY

Attached please find the certified copy of the foreign application from which priority is claimed for this case:

Country : Finland
Application Number : 20000141
Filing Date : 24 January 2000

WARNING: "When a document that is required by statute to be certified must be filed, a copy, including a photocopy or facsimile transmission of the certification is not acceptable." 37 CFR 1.4(f) (emphasis added.)

SIGNATURE OF ATTORNEY

Clarence A. Green

Reg. No.: 24,622

Type or print name of attorney

Tel. No.: (203) 259-1800

Perman & Green, LLP

Customer No.: 2512

P.O. Address

425 Post Road, Fairfield, CT 06430

NOTE: The claim to priority need be in no special form and may be made by the attorney or agent if the foreign application is referred to in the oath or declaration as required by § 1.63.

CERTIFICATE OF MAILING/TRANSMISSION (37 CFR 1.8a)

I hereby certify that this correspondence is, on the date shown below, being:

MAILING

☒ deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to the Commissioner of Patents and Trademarks, Washington, D.C. 20231

FACSIMILE

☐ transmitted by facsimile to the Patent and Trademark Office

Signature

DEBORAH J. CLARK
(type or print name of person certifying)

Date: 3/27/01

(Transmittal of Certified Copy [5-4])

PATENTTI- JA REKISTERIHALLITUS
NATIONAL BOARD OF PATENTS AND REGISTRATION

Helsinki 23.1.2001



ETUOIKEUSTODISTUS
PRIORITY DOCUMENT

CERTIFIED COPY OF
PRIORITY DOCUMENT



Hakija
Applicant

Nokia Mobile Phones Ltd
Espoo

Patenttihakemus nro
Patent application no

20000141

Tekemispäivä
Filing date

24.01.2000

Etuoikeushak. no
Priority from appl.

FI 20000122

Tekemispäivä
Filing date

21.01.2000

Kansainvälinen luokka
International class

H04N

Rekinnön nimitys
Title of invention

"A method for filtering digital images, and a filtering device"
(Menetelmä digitaalisten kuvien suodattamiseksi ja suodatin)

Täten todistetaan, että oheiset asiakirjat ovat tarkkoja jäljennöksiä patentti- ja rekisterihallitukselle alkuaan annetuista selityksestä, patenttivaatimuksista, tiivistelmästä ja piirustuksista.

This is to certify that the annexed documents are true copies of the description, claims, abstract and drawings originally filed with the Finnish Patent Office.

Pirjo Kaila
Pirjo Kaila
Tutkimussihteeri

Maksu 300,- mk
Fee 300,- FIM

A method for filtering digital images, and a filtering device

The present invention relates to a method for removing visual artefacts from a frame of a digital image, which has been coded by blocks and then decoded, in which method at least one pixel from at least one side of a block boundary is selected for filtering, filtering is performed on the block boundary between two adjacent blocks, and the blocks are scanned in a certain order. The present invention also relates to a device for removing visual artefacts from a frame of a digital image, which has been coded by blocks and then decoded, which device comprises means for selecting at least one pixel from at least one side of a block boundary for filtering, means for performing filtering on a block boundary between two adjacent blocks, and means for scanning the blocks in a certain order. The present invention also relates to an encoder, decoder, and codec comprising means for coding and decoding a digital image by blocks, which encoder comprises means for selecting at least one pixel from at least one side of a block boundary for filtering, means for performing filtering on a block boundary between two adjacent blocks, and means for scanning the blocks in a certain order. The present invention relates furthermore to a mobile terminal comprising a video codec, which comprises means for coding and decoding a digital image by blocks, which codec comprises means for selecting at least one pixel from at least one side of a block boundary for filtering, means for performing filtering on a block boundary between two adjacent blocks, and means for scanning the blocks in a certain order. The present invention relates furthermore to a storage medium for storing a software program comprising machine executable steps for coding and decoding a digital video signal by blocks, for selecting at least one pixel from at least one side of a block boundary for filtering, for performing filtering on a block boundary between two adjacent blocks, and for scanning the blocks in a certain order.

An arrangement like the one shown in Figure 1 is generally used for transferring a digital video sequence in compressed form. The digital video sequence is formed of sequential frames. In some prior art digital video transmission systems, for example ITU-T H.261/H.263 recommendations, three frame types are defined: an I-frame (Intra), a P-frame (Predicted or Inter), and a B-frame (Bi-directional). The I-frame

is generated solely on the basis of information contained in the image itself, wherein at the receiving end, this I-frame can be used to form the entire image. P-frames are formed on the basis of a preceding I-frame or P-frame, wherein at the receiving stage the preceding I-frame or P-frame is correspondingly used together with the received P-frame in order to reconstruct the image. In the composition of P-frames, for instance motion compensation is used to compress the quantity of information. B-frames are formed on the basis of one or more preceding P-frames or I-frames and/or one or more following P- or I-frames.

The frames are further divided into blocks. One frame can comprise different types of blocks. A predicted frame (e.g. Inter frame) may also contain blocks that are not predicted. In other words, some blocks of a P-frame may in fact be intra coded. Furthermore, some video coders may use the concept of independent segment decoding in which case several blocks are grouped together to form segments that are then coded independently from each other. All the blocks within a certain segment are of the same type. For example, if a P-frame is composed mainly of predicted blocks and some Intra-coded blocks, the frame can be considered to comprise at least one segment of intra blocks and at least one segment of predicted blocks.

In the YUV colour model, the image is represented by a luminance component and two chrominance components. The luminance information in the image typically is transformed with full spatial resolution. Both chrominance signals are spatially subsampled, for example a field of 16×16 pixels is subsampled into a field of 8×8 pixels. The differences in the block sizes are primarily due to the fact that the eye does not discern changes in chrominance equally well as changes in luminance, wherein a field of 2×2 pixels is encoded with the same chrominance value.

Typically, image blocks are grouped together to form macroblocks of 2×2 blocks. The macroblock contains usually 16 pixels by 16 rows of luminance samples, the mode information, and possible motion vectors. The macroblock is divided into four 8×8 luminance blocks and to two 8×8 chrominance blocks. Scanning (and encoding/decoding) proceeds

macroblock by macroblock, conventionally from the top-left to the bottom-right corner of the frame. Inside one macroblock the scanning (and encoding/decoding) order is from the top-left to the bottom-right corner of the macroblock.

5

Referring to figure 1, which illustrates a typical encoding and decoding system (codec) used, for example, in the transmission of digital video, a current video frame to be coded comes to the transmission system 10 as input data $I_n(x,y)$. In the differential summer 11 it is transformed into a prediction error frame $E_n(x,y)$ by subtracting from it a prediction frame $P_n(x,y)$ formed on the basis of a previous image. The prediction error frame is coded in block 12 in the manner described hereinafter, and the coded prediction error frame is directed to a multiplexer 13. To form a new reconstructed frame, the coded prediction error frame is also directed to a decoder 14, which produces a decoded prediction error frame $\hat{E}_n(x,y)$ which is summed in a summer 15 with the prediction frame $P_n(x,y)$, resulting in a reconstructed frame $\hat{I}_n(x,y)$. The reconstructed frame is saved in a frame memory 16. To code the next frame, the reconstructed frame saved in the frame memory is read as a reference frame $R_n(x,y)$ and is transformed into a new prediction frame $P_n(x,y)$ in a motion compensation and prediction block 17 according to the formula

20

$$P_n(x,y) = R_n[x + Dx(x,y), y + Dy(x,y)] \quad (1)$$

25

The pair of numbers $[Dx(x,y), Dy(x,y)]$ is called the motion vector of the pixel at location (x,y) and the numbers $Dx(x,y)$ and $Dy(x,y)$ are the horizontal and vertical shifts of the pixel. They are calculated in a motion estimation block 18. The set of motion vectors $[Dx(\cdot), Dy(\cdot)]$ consisting of all motion vectors related to the pixels of the frame to be compressed is also coded using a motion model comprising basis functions and coefficients. The basis functions are known to both the encoder and the decoder. The coefficient values are coded and directed to the multiplexer 13, which multiplexes them into the same data stream with the coded prediction error frame for sending to a receiver. In this way the amount of information to be transmitted is dramatically reduced.

30

35

Some frames can be partly, or entirely, so difficult to predict using only the reference frame $R_n(x,y)$ that it is not practical to use motion compensated prediction when coding them. These frames or parts of frames are coded using intracoding without any prediction from the reference frame $R_n(x,y)$, and accordingly motion vector information relating to them is not sent to the receiver. In prior art, for I-frames or those parts of P-frames which are intra-coded, another kind of prediction may be employed, namely intra prediction. In this case, the reference is formed by the previously decoded and reconstructed blocks which are part of the same frame (or slice if independent segment decoding is used).

In the receiver 20, a demultiplexer 21 separates the coded prediction error frames and the motion information transmitted by the motion vectors and directs the coded prediction error frames to a decoder 22, which produces a decoded prediction error frame $\hat{E}_n(x,y)$, which is summed in a summer 23 with the prediction frame $P_n(x,y)$ formed on the basis of a previous frame, resulting in a decoded and reconstructed frame $\hat{I}_n(x,y)$. The decoded frame is directed to an output 24 of the decoder and at the same time saved in a frame memory 25. When decoding the next frame, the frame saved in the frame memory is read as a reference frame $R_n(x,y)$ and transformed into a new prediction frame in the motion compensation and prediction block 26, according to formula (1) presented above.

The coding method used in the coding of prediction error frames and in the intracoding of a frame or part of a P-frame to be sent without using motion prediction, is generally based on a transformation, the most common of which is Discrete Cosine Transformation, DCT. The frame is divided into adjacent blocks sized e.g. 8 x 8 pixels. The transformation is calculated for the block to be coded, resulting in a series of terms. The coefficients of these terms are quantized on a discrete scale in order that they can be processed digitally. Quantization causes rounding errors, which can become visible in an image reconstructed from blocks, so that there is a discontinuity of pixel values at the boundary between adjacent blocks. Because a certain decoded frame is used to calculate the prediction frame for subsequent predicted (P) frames, these errors can be propagated in sequential

frames, thus causing visible edges in the image reproduced by the receiver. Image errors of this type are called blocking artefacts. Furthermore, if intra-prediction is used, blocking artefacts may also propagate from block to block within a given frame. In this case
5 blocking artefacts typically lead to visual effects which are specific to the type of intra prediction used. It should therefore be appreciated that there exists a significant technical problem relating to the spatial and temporal propagation of blocking artefacts in digital images that are coded for transmission and subsequently decoded.

10 The principles presented above are also applicable to a situation where segmented frames are used. In that case the coding and decoding is performed in segments of the frame, according to the type of blocks in each segment.

15 Some prior art methods are known for removing blocking artefacts. These methods are characterized by the following features:

20 - determining which pixels require value correction in order to remove a blocking artefact,

25 - determining a suitable low-pass filtering for each pixel to be corrected, based on the values of other pixels contained by a filtering window placed around the pixel,

- calculating a new value for the pixel to be corrected, and

- rounding the new value to the closest digitized pixel value.

30 Factors that influence the selection of a filter and the decision to use filtering can be, for example, the difference between the values of pixels across the block boundary, the size of the quantization step of the coefficients received as the transformation result, and the difference of the pixel values on different sides of the pixel being processed.

35 In prior art methods the filtering of blocking and other types of visual artefacts is performed frame by frame, *i.e.* the whole frame is first decoded and then filtered. As a result, the effects of blocking artefacts

easily propagate within a frame or from one frame to the next when prior art methods are used. This is especially true when predictive intracoding is used.

5 It has been found that prior art methods also tend to remove lines that belong to real features of the image. On the other hand, prior art methods are not always capable of removing all blocking or blocking related artefacts.

10 A primary objective of the method according to the invention is to limit the propagation of blocking artefacts within frames and from one frame to the next. Another objective of the present invention is to present a new kind of filtering arrangement for removing blocking and other blocking related artefacts which are especially visible when predictive
15 intracoding is used. The invention also has the objective that the method and associated device operate more reliably and efficiently than prior art solutions.

20 The objectives of the invention are achieved by performing block boundary filtering in a particular order and substantially immediately after an image block is decoded and there is at least one block boundary available to be filtered. Among other things, this provides the advantage that the spatial and temporal propagation of blocking and other visual artefacts is limited to a greater degree than in prior art
25 methods. Furthermore, the results of previous block boundary filtering operations can be utilised in the coding, decoding and filtering of subsequent blocks. In other words, pixel values modified/corrected in connection with the filtering of one boundary are then available for use when coding, decoding and filtering other block boundaries.

30 The method according to the invention for removing blocking and other visual artefacts (which are mainly caused by blocking artefacts) from a frame that has been coded by blocks, is characterized in that filtering on a block boundary is performed substantially immediately after the
35 block is decoded, and that the order of filtering the boundaries is predetermined.

The invention also relates to a device for implementing the method according to the invention. The device according to the invention is characterized in that filtering on a block boundary is performed substantially immediately after the block is decoded, and that the order of filtering the boundaries is predetermined.

The invention also relates to an encoder for encoding digital images that implements the method of the invention. The encoder according to the invention is characterized in that filtering on a block boundary is performed substantially immediately after the block is decoded, and that the order of filtering the boundaries is predetermined.

The invention also relates to a decoder for decoding digital images that implements the method according to the invention. The decoder according to the invention is characterized in that filtering on a block boundary is performed substantially immediately after the block is decoded, and that the order of filtering the boundaries is predetermined.

The invention also relates to a codec for encoding and decoding digital images that implements the method according to the invention. The codec according to the invention is characterized in that filtering on a block boundary has been performed substantially immediately after the block is decoded, and that the order of filtering the boundaries is predetermined.

The invention also relates to a mobile terminal having digital image transmission capability and implementing the method according to the invention. The mobile terminal according to the invention is characterized in that filtering on a block boundary is performed substantially immediately after the block is decoded, and that the order of filtering the boundaries is predetermined.

The invention also relates to a storage medium storing a software program with instructions implementing the method according to the invention. The storage medium according to the invention is characterized in that the software program further comprises machine executable steps for performing filtering on a block boundary

substantially immediately after the block is decoded, and that the order of filtering the boundaries is predetermined.

5 Because blocking artefacts occur at block boundaries, the filtering method according to the invention is only applied to pixels at block boundaries and the immediate vicinity thereof. Edges that are part of the image can reside anywhere in the image area. In order that only pixels containing blocking artefacts are selected for corrective filtering and that the quality of edges that are part of the image is not affected
10 during filtering, the following assumptions were made in the study that resulted in the invention:

15 The changes in pixel value associated with edges that are part of the image, are generally larger than those associated with blocking artefacts, and

Those edges within the image, where the pixel value change is small do not suffer considerably from the rounding of the pixel value difference caused by filtering.

20 Because an image to be coded is generally divided into blocks both vertically and horizontally, the image contains both vertical and horizontal block boundaries. With regard to vertical block boundaries, there are pixels to the right and left of the boundary, and with regard to horizontal
25 block boundaries, there are pixels above and below the boundary. In general, the location of the pixels can be described as being on a first or a second side of the block boundary.

30 The method and associated device according to the invention significantly limits propagation of visual anomalies due to blocking artefacts from previously reconstructed blocks to subsequently reconstructed blocks within the same frame, or within the same segment, if independent segment decoding is used. Propagation of blocking artefacts within frames and from one frame to the next is also reduced. By using the
35 method and device according to the invention a larger number of blocking and blocking related artefacts can be removed without weakening the real image edges unreasonably.

In the following, the invention will be described in more detail with reference to the preferred embodiments and the accompanying drawings, in which

- 5 Figure 1 represents a digital video codec according to prior art,
- Figure 2 represents an advantageous block scanning order in the method according to a preferred embodiment of the invention,
- 10 Figure 3 represents an advantageous block boundary filtering order after reconstruction of a block according to a preferred embodiment of the invention,
- 15 Figure 4 represents an advantageous filtering order in the preferred method according to the invention,
- Figure 5 represents a digital image block transfer system for implementing a method according to the invention,
- 20 Figure 6 represents a flow diagram of a method according to the invention, and
- 25 Figure 7 is a schematic representation of a portable teleconferencing device implementing a method according to the invention.

In the following description of the invention and its preferred embodiments, reference will be made mostly to Figures 2 to 6.

30 In the following, the operation of a digital image decoder is described. In a digital image transfer system according to the invention, such as that illustrated in figure 5, the block and block boundary scanning order used in the encoder and decoder are the same, *i.e.* known to both encoder and decoder. However, the particular scanning order chosen is

35 not essential for implementation of the method according to the invention. Figure 2 shows an advantageous scanning order of a frame comprising groups of blocks, *e.g.* macroblocks. First, the top-left block B1 is decoded, *i.e.* pixel values representing *e.g.* the luminance

information of the block are reconstructed and saved into a frame buffer. Then, the top-right block B2 is decoded and saved into the frame buffer. Now, the first vertical boundary R12 between the top-left block B1 and top-right block B2 has a decoded block at both sides, so the boundary R12 can be filtered. Advantageously only those pixel values which are changed by the filtering are updated in the frame buffer. There are many known methods for performing filtering on the block boundary. One prior art filtering method which can be implemented with the invention is disclosed in international patent publication WO 98/41025 which is to be considered as a reference here.

Next, the bottom-left block B3 of the group of blocks in question is decoded and saved into the frame buffer. Now, the first horizontal boundary R13 between the top-left block B1 and bottom-left block B3 has a decoded block on both sides, wherein the first horizontal boundary R13 can also be filtered. In the filtering of the first vertical boundary R12 some pixel values near the first horizontal boundary R13 may have changed. Advantageously, these modified values are used in the filtering of the first horizontal boundary R13. This helps to further restrict propagation of visual artefacts from previously reconstructed blocks to subsequent reconstructed blocks within the same frame, or same segment, if independent segment decoding is used.

Now the fourth block B4 inside the macroblock is decoded and saved into the frame buffer. When decoding of the fourth block B4 is complete there exist two additional boundaries having a decoded block on either side: the second vertical boundary R34 and the second horizontal boundary R24. Therefore, both of said boundaries R34, R24 can now be filtered. In this advantageous embodiment of the method according to the invention the filtering is performed such that the second vertical boundary R34 is filtered first, the filtering result is saved in the frame buffer, and the second horizontal boundary R24 is filtered subsequently. In a general case, if two boundaries (e.g. to the left of and above) a current block are filtered then the changed pixel values resulting from the first filtered boundary are used when filtering the other boundary.

In an advantageous embodiment of the invention, for a certain block, filtering can be performed across one, two, three, four, or none of the boundaries of the block, depending on which scanning order is adopted for coding the blocks inside a frame, or segment. In the preferred mode of implementation the order in which blocks are reconstructed is illustrated in Figure 2. As depicted, four blocks are grouped together to form macroblocks of 2x2 blocks. Scanning then proceeds macroblock by macroblock from the top-left to the bottom-right corner of the frame. Inside one macroblock the scanning order is from the top-left to the bottom-right corner of the macroblock. Due to this particular scanning order, in the preferred mode of implementation a maximum of two boundaries (to the left of and/or above) a block become available for filtering, when a block is reconstructed. The order in which block boundaries are advantageously examined for filtering is illustrated in Figure 3 (left boundary first and then the upper one). The remaining boundaries, i.e. to the right and below, are filtered only when reconstruction of an adjacent block to the right and, respectively, below is completed. In the event that the block is located at the frame border or at a segment border, the corresponding block boundary/boundaries is/are not filtered since there is no adjacent block to filter across the common boundary. In the preferred mode of implementation the order in which the block boundaries are filtered inside one frame is illustrated in Figure 4 for a small frame size of 6x4 blocks. The numbers on the block boundaries represent the filtering order according to an advantageous embodiment of the present invention. In practical applications the frame typically comprises more than 6x4 blocks, but it is clear from the description above how the preferred filtering order can be extended to frames and segments which comprise more (or less) than 6x4 blocks.

In general, the system described in this invention can be applied to block-based still image coding as well as to all kinds of coding in block-based video coders: I, P, B, coded and not-coded. The filtering described in this invention works for a frame that is divided into NxM blocks for coding.

In the method according to the invention, filtering is applied only across those block boundaries that are adjacent to other previously

reconstructed blocks as soon as a block is reconstructed. If independent segment decoding is used, filtering is only applied across those block boundaries that are adjacent to previously reconstructed blocks belonging to the same segment as the current block.

5

An essential feature of the method according to the invention is the fact that the result of filtering is made available to the digital image coding system before reconstructing a subsequent block in the frame. This is especially advantageous for predictive intracoding where prediction of a block is performed with reference to previously reconstructed blocks within the same frame (or segment, if independent segment decoding is utilised). The current scheme is advantageous for any given block coding scheme which uses prediction of a block from previously reconstructed blocks inside the same frame or the same segment. In addition to the advantages achieved by prior art solutions, this way of operation prevents propagation of visual artefacts from previously reconstructed blocks to subsequently reconstructed blocks within the same frame, or the same segment, if independent segment decoding is used. Reconstruction of a certain block is therefore dependent on filtered data derived from previously reconstructed blocks. In order to avoid encoder-decoder mismatch, the decoder not only has to execute the same scheme of filtering but must also perform filtering operations in the same order as the encoder. The method also prevents propagation of blocking artefacts from one frame to the next, because blocking artefacts in a frame used e.g. in prediction are reduced by the method according to the invention.

25

30

35

In the following, the transmission and reception of video frames in a video transmission system is described with reference to the digital image transfer system presented in Figure 5 and the flow diagram in Figure 6. Operation of the block boundary filtering method according to the invention will first be described in connection with the encoder of the transmission system, in the situation that a frame of a digital image sequence is encoded in Intra (I-frame) format and using some form of Intra block prediction, in which a block of the Intra frame may be coded with reference to other previously coded Intra blocks within the same frame. Filtering of block boundaries in the decoder of the transmission system will then be described for a corresponding Intra-coded frame

received for decoding at the receiver. Finally, application of the block boundary filtering method according to the invention to Inter-coded frames (P-frames) will be described.

- 5 Assuming that a frame is to be encoded in Intra format using some form of Intra prediction, encoding of the frame proceeds as follows. The blocks of the frame to be coded are directed one by one to the encoder 50 of the video transfer system presented in Figure 5. The blocks of the frame are received from a digital image source, e.g. a camera or a
10 video recorder (not shown) at an input 27 of the image transfer system. The frame can be stored temporarily in a frame memory (not shown), or alternatively, the encoder receives the input data directly block by block.
- 15 The blocks are directed one by one to a prediction method selection block 35 that determines whether the pixel values of the current block to be encoded can be predicted on the basis of previously Intra-coded blocks within the same frame or segment. In order to do this, the prediction method selection block 35 receives input from a frame buffer
20 of the encoder 33, which contains a record of previously encoded and subsequently decoded and reconstructed Intra blocks. In this way, the prediction method selection block can determine whether prediction of the current block can be performed on the basis of previously decoded and reconstructed blocks. Furthermore, if appropriate decoded blocks
25 are available, the prediction method selection block 35 can select the most appropriate method for predicting the pixel values of the current block, if more than one such method may be chosen. It should be appreciated that in certain cases, prediction of the current block is not possible because appropriate blocks for use in prediction are not
30 available in the frame buffer 33. It should also be appreciated that the prediction method selection block is an optional element in the coding system and is present in the situation that more than one Intra prediction method can be selected. In the situation where more than one prediction method is available, information about the chosen
35 prediction method is supplied to multiplexer 13 for further transmission to the decoder. It should also be noted that in some prediction methods, certain parameters necessary to perform the prediction are transmitted to the decoder. This is, of course, dependent on the exact

implementation adopted and in no way limits the application of the block boundary filter according to the invention.

Pixel values of the current block are predicted in the Intra prediction block 34. The Intra prediction block 34 receives input concerning the chosen prediction method from the prediction method selection block 35 and information concerning the blocks available for use in prediction from frame buffer 33. On the basis of this information, the Intra prediction block 34 constructs a prediction for the current block. The predicted pixel values for the current block are sent to a differential summer 28 which produces a prediction error block by taking the difference between the pixel values of the predicted current block and the actual pixel values of the current block received from input 27. Next, the error information for the predicted block is coded in the prediction error coding block in an efficient form for transmission, for example using a discrete cosine transform (DCT). The coded prediction error block is sent to multiplexer 13 for further transmission to the decoder.

The encoder of the digital image transmission system also includes decoding functionality. The encoded prediction error of the current block is decoded in prediction error decoding block 30 and is subsequently summed in summer 31 with the predicted pixel values for the current block. In this way, a decoded version of the current block is obtained. The decoded current block is then directed to a block boundary filter 32, implemented according to the method of the invention. Now referring to the flow chart of Figure 6, the block boundary filter 32 examines 602, 604, if the current (just decoded) block has boundaries that can be filtered. In order to determine if such boundaries exist, the block boundary filter examines the contents of the frame buffer 33. If more than one such boundary exists, the block boundary filter determines 603 the filtering order to be used in filtering the boundaries. If at least one boundary is found, the block boundary filter retrieves 605 those pixel values that belong to the adjacent block of the present boundary to be used in the filtering process. The block boundary filter performs the filtering 606 according to a preferred filtering method and updates at least the modified pixel values in the current block and the values of pixels filtered in previously decoded blocks stored in the frame buffer 33. The block boundary filter then

examines 608 whether there are still boundaries to be filtered. If other boundaries are to be filtered the process returns to step 605. The block filter performs analogous operations on each block of the frame being coded until all blocks have been encoded. As each block is filtered it is made available for use *e.g.* in the prediction and/or filtering subsequent blocks by storing it in the frame buffer 33.

The operation of the block boundary filtering method according to the invention will now be described in connection with the receiver of a digital image transmission system. Here, use of the filter is described in connection with the decoding of a frame, assumed to have been encoded in Intra format using some form of Intra prediction method in which the pixel values of a current block are predicted on the basis of previously encoded image blocks within the same frame.

Here it is also assumed that the receiver receives the blocks that form a digital image frame one by one from a transmission channel. It should be appreciated that in other embodiments, the receiver may receive a complete frame to be decoded, or alternatively may retrieve the digital image to be decoded from a file present on some form of storage medium. In any case, operation of the block boundary filtering method according to the invention is performed on a block-by-block basis, as described below.

In the receiver 60, a demultiplexer receives and demultiplexes coded prediction error blocks and prediction information transmitted from the encoder 50. Depending on the prediction method in question, the prediction information may include parameters used in the prediction process. It should be appreciated that in the case that only one Intra prediction method is used, information concerning the prediction method used to code the blocks is unnecessary, although it may still be necessary to transmit parameters used in the prediction process. In Figure 5, dotted lines are used to represent the optional transmission and reception of prediction method information and/or prediction parameters. Assuming more than one Intra prediction method may be used, information concerning the choice of prediction method for the current block being decoded is provided to Intra prediction block 41. Intra prediction block 41 examines the contents of frame buffer 39 to

determine if there exist previously decoded blocks to be used in the prediction of the pixel values of the current block. If such image blocks exist, Intra prediction block 41 predicts the contents of the current block using the prediction method indicated by the received prediction method information and possible prediction-related parameters received from the encoder. Prediction error information associated with the current block is received by prediction error decoding block 36 which decodes the prediction error block using an appropriate method. For example, if the prediction error information was encoded using a discrete cosine transform, the prediction error decoding block performs an inverse DCT to retrieve the error information. The prediction error information is then summed with the prediction for the current image block in summer 37 and the output of the summer is applied to block boundary filter 38. Block boundary filter 38 applies boundary filtering to the newly decoded image block in a manner analogous to the block boundary filter of the encoder (block 32). Accordingly, block boundary filter 38 examines 602, 604, if the current (newly decoded) block has boundaries that can be filtered. In order to determine if such boundaries exist, the block boundary filter 38 examines the contents of frame buffer 39 which contains previously decoded and reconstructed image blocks. If more than one such boundary exists, the block boundary filter determines 603 the filtering order to be used in filtering the boundaries. Advantageously, this order is identical to that used in the boundary filter 32 of the encoder. If at least one boundary is found, the block boundary filter retrieves 605 those pixel values that belong to the adjacent block of the present boundary for use in the filtering process. The block boundary filter performs the filtering 606 according to a preferred filtering method (advantageously identical to that used in the encoder) and updates at least the modified pixel values in the current block and the values of pixels filtered in previously decoded blocks stored in the frame buffer 39. The block boundary filter then examines 608 whether there are still boundaries to be filtered. If other boundaries are to be filtered the process returns to step 605.

35 The block filter performs analogous operations on each block of the frame, substantially immediately after each block is decoded, until all blocks have been decoded and their boundaries appropriately filtered. As each block is filtered it is made available for use e.g. in the

prediction and/or filtering subsequent blocks by storing it in the frame buffer 39. Furthermore, as each block is decoded and its boundaries filtered by applying the method according to the invention, it is directed to the output of the decoder 40, for example to be displayed on some form of display means. Alternatively, the image frame may be displayed only after the whole frame has been decoded and accumulated in the frame buffer 39.

In the paragraphs above, the method according to the invention was described in connection with the filtering of block boundaries in a frame coded in Intra format and further using Intra prediction methods. It should be appreciated that the method according to the invention may be applied in an exactly analogous manner for filtering block boundaries between Intra coded blocks that form part of an otherwise Inter-coded frame. Alternatively, the method may be applied to Inter coded image blocks. In this case, each Inter coded block is predicted based on information concerning its motion between a current frame and a reference frame and the operations of the encoder are as follows: A prediction error block is formed based on the difference between the prediction for the block and the actual contents of the block. The prediction error block is coded in a way known as such, for example using a DCT and transmitted to the decoder together with information, for example motion coefficients, representing the motion of the block. In the encoder, the coded prediction error is further decoded and summed with the prediction for the current block to produce a decoded and reconstructed block that forms part of a prediction reference frame to be used in connection with motion compensated prediction coding of the next frame in the sequence. As was the case in the example given above concerning Intra coding, a block boundary filter can be implemented for use in connection with Inter coded blocks in such a way that it receives and filters Inter coded blocks of the current frame substantially immediately after they have been decoded. An equivalent arrangement may be used in connection with the decoding of Inter coded blocks received at the receiver of a digital image transmission system.

The block carrying out the filtering method according to the invention is particularly advantageously implemented in a digital signal processor or

a corresponding general purpose device suited to processing digital signals, which can be programmed to apply predetermined processing functions to signals received as input data. The measures according to Figure 6 can be carried out in a separate signal processor or they can
5 be part of the operation of such a signal processor which also contains other arrangements for signal processing.

A storage medium can be used for storing a software program comprising machine executable steps for performing the method
10 according to the invention. Then, in an advantageous embodiment of the invention, the software program can be read from the storage medium to a device comprising programmable means, e.g. a processor, for performing the method of the invention.

15 In the method and device according to the invention, the number of pixels to be selected for filtering can vary, and it is not necessarily the same on different sides of the block boundary. The number of pixels may be adapted according to the general features of the image information contained by the frame. Furthermore, many filtering methods
20 can be applied with the present invention. In some intra-prediction methods it is not necessary to send the intra prediction information in addition to the coded differential blocks to the receiver 60. The definitions of filtering order above have also been intended as examples only.

25 A particularly advantageous use of the invention is in mobile teleconferencing applications, digital television receivers and other devices that at least receive and decode digital video images.

30 Figure 7 presents a simplified schematic diagram of a mobile terminal 41 intended for use as a portable teleconferencing device and applying the deblocking filter method according to the invention. The mobile terminal comprises advantageously at least display means 42 for displaying images, audio means 43 for audio information, keyboard 44 for
35 inputting e.g. user commands, radio part 45 for communicating with a mobile telecommunications network, processing means 46 for controlling the operation of the device, memory means 47 for storing information, and preferably a camera 48 for taking images.

The present invention is not solely restricted to the above presented embodiments, but it can be modified within the scope of the appended claims.

2
8
9
4
4

Claims:

1. A method for removing visual artefacts from a frame of a digital image, which has been coded by blocks (B1, B2, B3, B4) and then
5 decoded, in which method at least one pixel from at least one side of a block boundary (R12, R13, R24, R34) is selected for filtering, filtering is performed on the block boundary (R12, R13, R24, R34) between two adjacent blocks (B1, B2, B3, B4), and the blocks are scanned in a certain order, **characterized** in that filtering on the block boundary
10 (R12, R13, R24, R34) is performed substantially immediately after the block (B1, B2, B3, B4) is decoded, and that the order of filtering the boundaries is predetermined.
2. A method according to Claim 1, **characterized** in that after a block (B1, B2, B3, B4) is decoded it is examined (603, 604) to determine, if
15 there exists another decoded block (B1, B2, B3, B4) adjacent to said decoded block under examination, wherein if such a block is found, filtering is performed on the boundary (R12, R13, R24, R34) between said decoded block under examination and said other decoded block.
3. A method according to Claim 2, **characterized** in that if there
20 exists more than one decoded block (B1, B2, B3, B4) adjacent to said decoded block under examination, filtering is performed in a certain order on the boundaries (R12, R13, R24, R34) between said decoded block under examination and said other decoded blocks.
4. A method according to Claim 2 or 3, **characterized** in that a value
25 of at least one pixel selected for examination is corrected by filtering, and that at least one corrected value of filtered pixels is used in filtering at least on one other block boundary (R12, R13, R24, R34).
5. A method according to Claim 2, 3 or 4, **characterized** in that intra
30 prediction of a subsequent block is performed after the block (B1, B2, B3, B4) is decoded, that a value of at least one pixel selected for examination is corrected by filtering, and that at least one corrected value of filtered pixels is used in the intra prediction of at least one subsequent block.

6. A method according to Claim 2, 3, 4 or 5, **characterized** in that the blocks of the frame are grouped into macroblocks, wherein the frame is scanned macroblock by macroblock.
- 5 7. A method according to Claim 6, **characterized** in that the frame is scanned horizontally from top-left to bottom-right.
8. A method according to Claim 7, **characterized** in that in a situation where at least two boundaries are filtered after the block (B4) is decoded, the filtering order is selected such that the left boundary (R34) of said block is filtered before the top boundary (R24).
- 10 9. A device for removing visual artefacts from a frame of a digital image, which has been coded by blocks (B1, B2, B3, B4) and then decoded, which device comprises means for selecting at least one pixel from at least one side of a block boundary (30) for filtering, means for performing filtering on a block boundary (R12, R13, R24, R34) between
15 two adjacent blocks (B1, B2, B3, B4), and means for scanning the blocks in a certain order, **characterized** in that filtering on the block boundary (R12, R13, R24, R34) is performed substantially immediately after the block (B1, B2, B3, B4) is decoded, and that the order of filtering the boundaries is predetermined.
- 20 10. A device according to Claim 9, **characterized** in that it comprises means for determining, if there exists another decoded block (B1, B2, B3, B4) adjacent to said decoded block under examination, wherein if such a block is found, filtering is performed on the boundary (R12, R13, R24, R34) between said decoded block under examination and said
25 other decoded block.
11. A device according to Claim 10, **characterized** in that it comprises means for examining, if there exists more than one decoded block (B1, B2, B3, B4) adjacent to said decoded block under examination, wherein the means for performing filtering on a block boundary (R12, R13, R24, R34) comprises means for performing the filtering in a certain order on
30 the boundaries (R12, R13, R24, R34) between said decoded block under examination and said other decoded blocks.
12. A device according to Claim 10 or 11, **characterized** in that it comprises a filter for correcting a value of at least one pixel selected for

examination, means for saving the results of filtering on a block boundary (R12, R13, R24, R34), and means for using the saved results in filtering at least on one other block boundary (R12, R13, R24, R34).

5 13. A device according to Claim 10, 11 or 12, **characterized** in that it comprises means for performing intra prediction of a subsequent block after the block (B1, B2, B3, B4) is decoded, a filter for correcting a value of at least one pixel selected for examination, means for saving the results of filtering on a block boundary (R12, R13, R24, R34), and means for using the saved results in intra prediction of at least on one
10 other block boundary (R12, R13, R24, R34).

14. A device according to any of the Claims 10 to 13, **characterized** in that the blocks of the frame are grouped into macroblocks, wherein the frame is arranged to be scanned macroblock by macroblock.

15 15. A device according to Claim 14, **characterized** in that the frame is scanned horizontally from top-left to bottom-right.

16. A device according to Claim 15, **characterized** in that the filtering order is selected such that the left boundary (R34) of said block is filtered before the top boundary (R24).

20 17. An encoder (50) comprising means for coding and decoding a digital image by blocks (B1, B2, B3, B4), which encoder comprises means for selecting at least one pixel from at least one side of a block boundary (30) for filtering, means for performing filtering on a block boundary (R12, R13, R24, R34) between two adjacent blocks (B1, B2, B3, B4), and means for scanning the blocks in a certain order,
25 **characterized** in that filtering on the block boundary (R12, R13, R24, R34) is performed substantially immediately after the block (B1, B2, B3, B4) is decoded, and that the order of filtering the boundaries is predetermined.

30 18. A decoder (60) comprising means for decoding a digital image by blocks (B1, B2, B3, B4), which decoder comprises means for selecting at least one pixel from at least one side of a block boundary (30) for filtering, means for performing filtering on a block boundary (R12, R13, R24, R34) between two adjacent blocks (B1, B2, B3, B4), and means for scanning the blocks in a certain order, **characterized** in that filtering

on the block boundary (R12, R13, R24, R34) is performed substantially immediately after the block (B1, B2, B3, B4) is decoded, and that the order of filtering the boundaries is predetermined.

5 19. A codec (50, 60) comprising means for coding and decoding a digital image by blocks (B1, B2, B3, B4), which codec comprises means for selecting at least one pixel from at least one side of a block boundary (30) for filtering, means for performing filtering on a block boundary (R12, R13, R24, R34) between two adjacent blocks (B1, B2, B3, B4), and means for scanning the blocks in a certain order,
10 **characterized** in that filtering on the block boundary (R12, R13, R24, R34) is performed substantially immediately after the block (B1, B2, B3, B4) is decoded, and that the order of filtering the boundaries is predetermined.

15 20. A mobile terminal comprising a video codec (50, 60), which comprises means for coding and decoding a digital image by blocks (B1, B2, B3, B4), which codec comprises means for selecting at least one pixel from at least one side of a block boundary (30) for filtering, means for performing filtering on a block boundary (R12, R13, R24, R34) between two adjacent blocks (B1, B2, B3, B4), and means for
20 scanning the blocks in a certain order, **characterized** in that filtering on the block boundary (R12, R13, R24, R34) is performed substantially immediately after the block (B1, B2, B3, B4) is decoded, and that the order of filtering the boundaries is predetermined.

25 21. A storage medium for storing a software program comprising machine executable steps for coding and decoding a digital video signal by blocks, for selecting at least one pixel from at least one side of a block boundary (30) for filtering, for performing filtering on a block boundary (R12, R13, R24, R34) between two adjacent blocks (B1, B2, B3, B4), and for scanning the blocks in a certain order, **characterized**
30 in that the software program further comprises machine executable steps for performing filtering on the block boundary (R12, R13, R24, R34) substantially immediately after the block (B1, B2, B3, B4) is decoded, and that the order of filtering the boundaries is predetermined.

Abstract:

The invention relates to a method for removing blocking and other blocking related visual artefacts from the frame of a digital image, which has been coded by blocks (B1, B2, B3, B4) and then decoded. In the method at least one pixel from at least one side of a block boundary (R12, R13, R24, R34) is selected for filtering. Filtering is performed on the block boundary (R12, R13, R24, R34) between two adjacent blocks (B1, B2, B3, B4). The blocks are scanned in a certain order. Filtering on the block boundary (R12, R13, R24, R34) is performed substantially immediately after the block (B1, B2, B3, B4) is decoded, and the order of filtering the boundaries is predetermined.

Fig. 4



L3

1/6

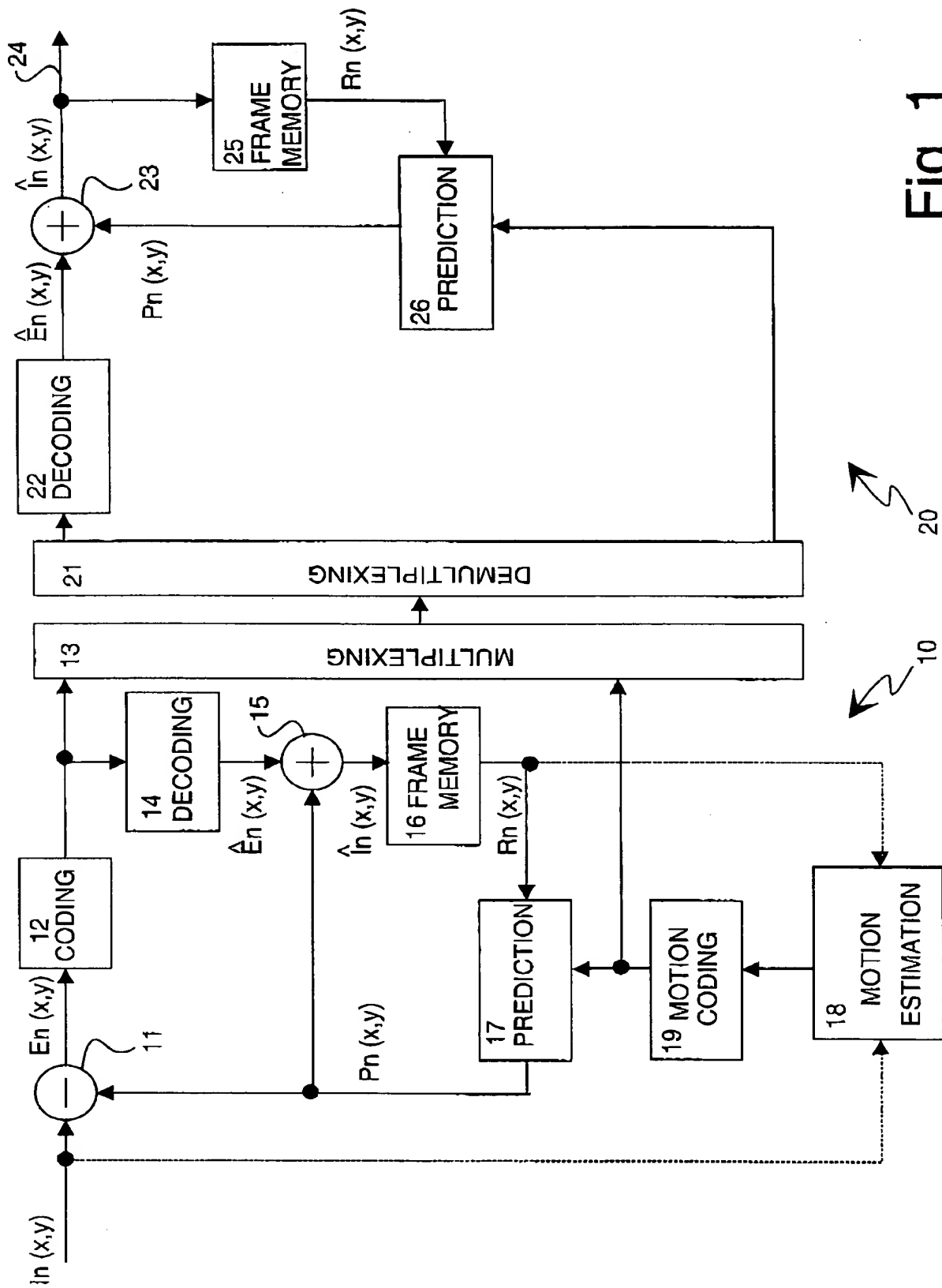


Fig. 1

B1	R12	1	2	5	6	9	10
		R13	B2	7	8	11	12
	R24	B3	3	4	13	14	15
		R34	B4	16	17	18	19
				20	21	22	23
				24			

Fig. 2

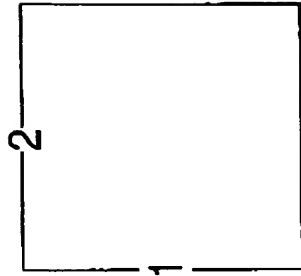


Fig. 3

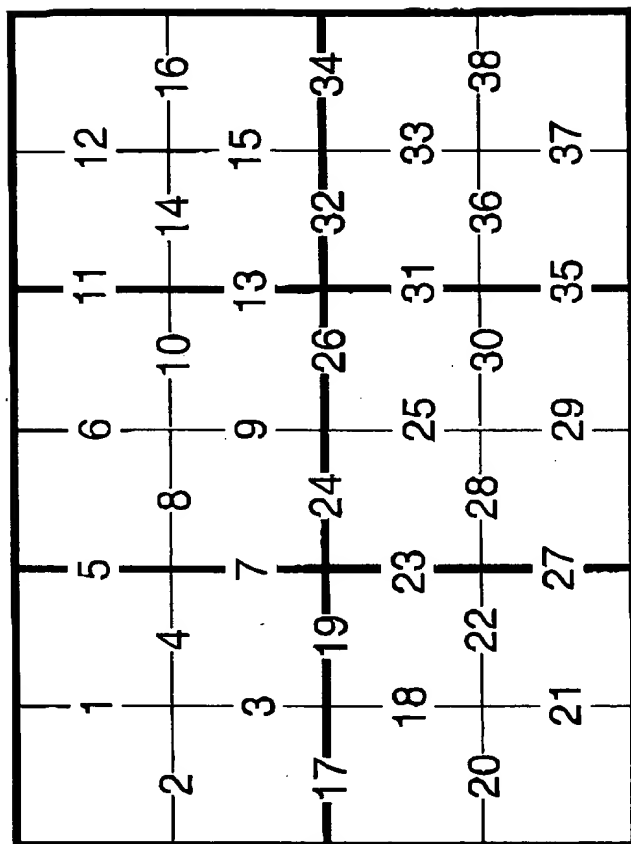


Fig. 4

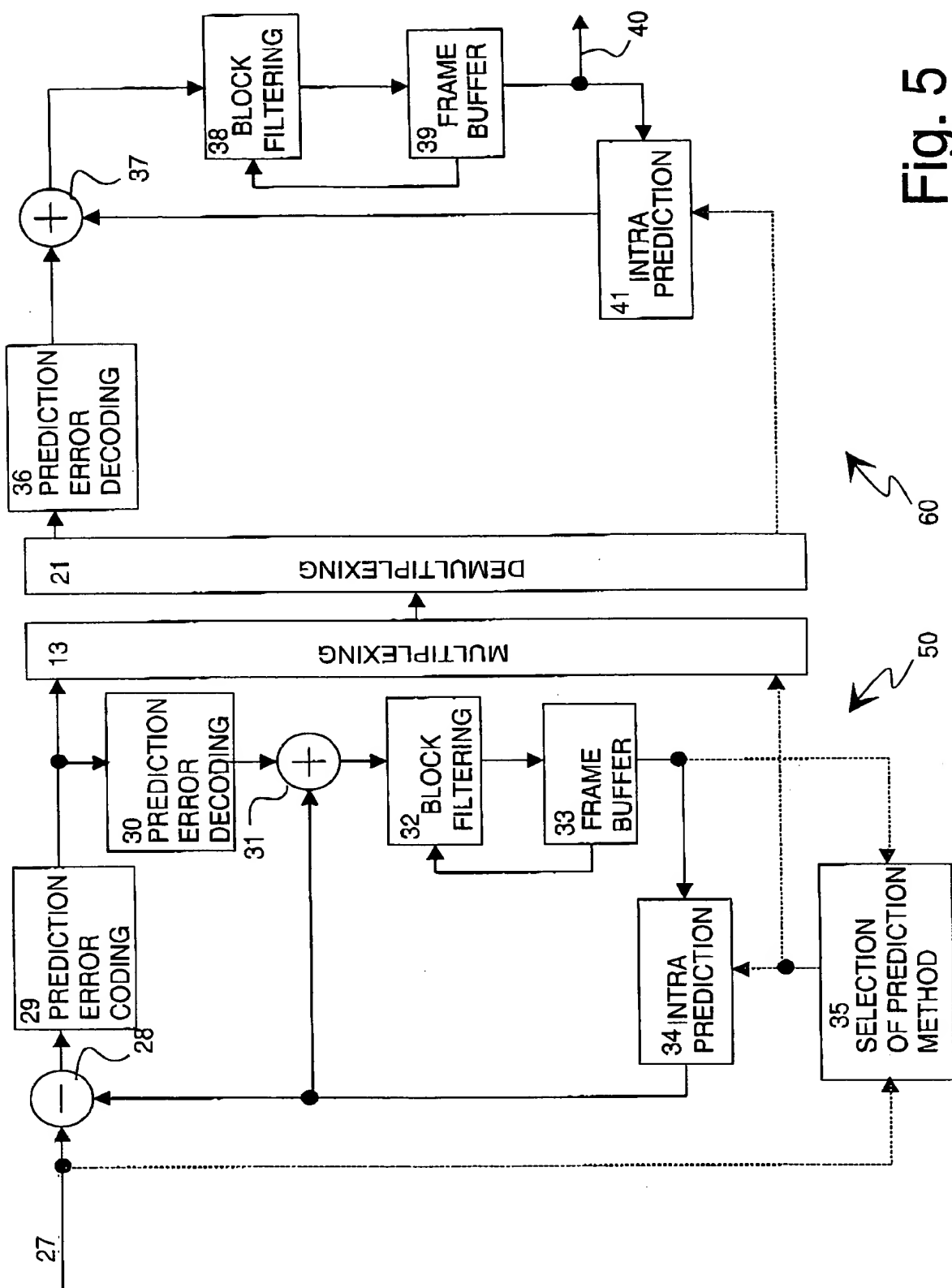


Fig. 5

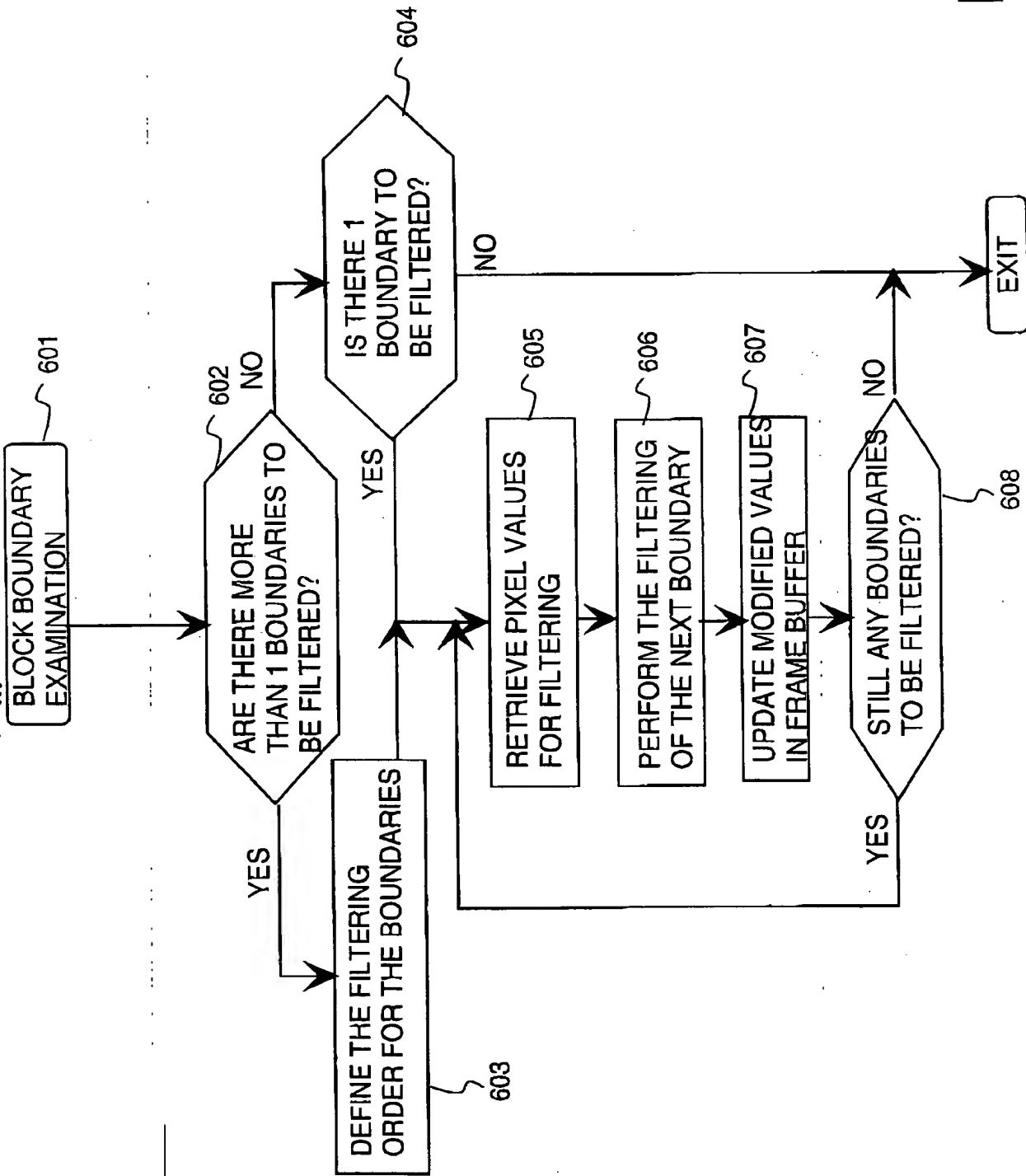


Fig. 6

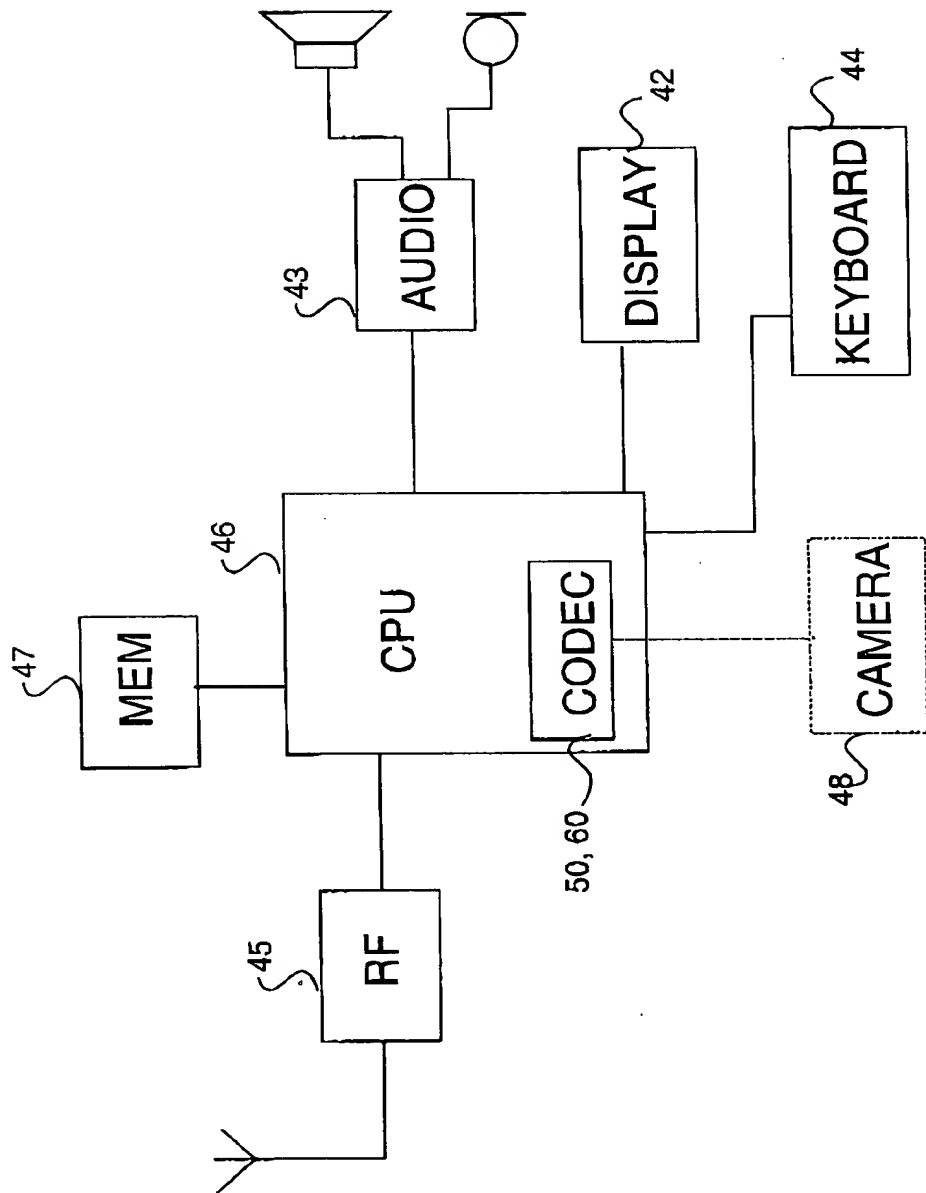


Fig. 7